

Investigative Report and Recommendations for the Kofa Bighorn Sheep Herd

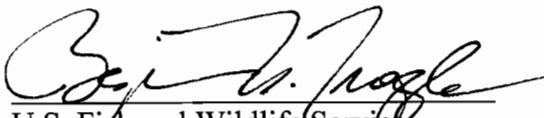
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Kofa National Wildlife Refuge

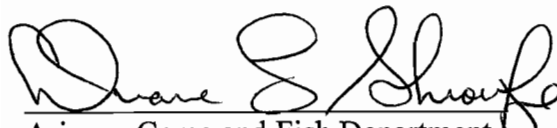
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Table of Contents

Part 1. Purpose and Need.....	4
Significance of Bighorn Sheep and History of Management	4
Part 2. Bighorn Sheep Mortality Factors and Management Strategies.....	6
<i>Habitat Considerations</i>	7
Population Response to Drought	7
Water Availability.....	8
<i>Biological Considerations</i>	10
Predation	11
Disease	15
Human Disturbance	16
Translocations	18
Hunting	19
<i>Other Considerations</i>	20
Livestock and Burros	20
Noxious and Invasive Plants.....	20
Wildfires	21
Mining.....	21
<i>Social Considerations</i>	21
Political Issues and Public Outreach.....	21
Volunteers	22
<i>Cost Considerations</i>	22
Part 3. Implementation.....	24
<i>Implementation Matrix</i>	25
Figures.....	27
<i>Figure 1. Bighorn sheep population estimates for Kofa NWR (Unit 45), 1981-2006*.</i>	27
<i>Figure 2. Annual precipitation at Kofa Mine station in the Kofa Mountains. Blue line represents 30-year mean.</i>	28
<i>Figure 3. Bighorn sheep waters with 3-mile radius circle drawn around “permanent” waterholes (red dots). Habitat outside circles lacks adequate water supplies. Green and blue dots are bighorn locations from fall surveys 1992-2003.</i>	29
<i>Figure 4. Example of bighorn sheep water in the Mohawk Mountains, Arizona (not on the refuge) constructed with new techniques that minimize visual impact. Most water storage and collection components are buried and not visible.</i>	30
Tables	31
<i>Table 1. Population estimates of bighorn sheep in game management units that surround the Kofa NWR (Units 45 and 44BS).</i>	31

<i>Table 2. Critical bighorn sheep waters on the Kofa and recommended management actions.</i>	32
<i>Table 3. History of translocations from Kofa National Wildlife Refuge.</i>	33
Literature Cited	35

Part 1. Purpose and Need

The Kofa National Wildlife Refuge (Kofa NWR) contains a major portion of the largest contiguous habitat for desert bighorn sheep (*Ovis canadensis mexicana*) in southwestern Arizona and historically has been home to a population averaging about 800 bighorns. The refuge has served as the primary source of sheep for translocations to reestablish and supplement extirpated or declining populations throughout southern Arizona, New Mexico, Texas, and Colorado. Recently, systematic aerial surveys indicated that a 50% decline in the size of the Kofa population may have occurred between the years 2000 and 2006. The regionally critical transplant program is halted until the population returns to historical numbers capable of supporting the transplants. The purpose of this plan is to provide an analysis of the probable causes of the decline and a strategic approach to a management program intended to lead to the recovery of this important wildlife resource.

The plan includes three sections. Part 1 describes the current problem and provides some historical context. The heart of the plan is Part 2, where issues are identified, and strategies to manage them are recommended. Part 3 is a concise matrix that contains prioritized implementation strategies.

Significance of Bighorn Sheep and History of Management

Bighorn sheep have captivated human interest since the earliest recorded time. Throughout the west, thousands of bighorn are depicted on cliff faces. More than any other North American mammal, the bighorn sheep symbolizes remote and wild places. They occupy the most inaccessible, rugged, and spectacular mountain ranges on the continent. Yet despite this allure, bighorn sheep management and research is relatively new when compared to other big game animals in North America, and many fundamental questions remain unanswered.

The State of Arizona first afforded legal protection for the bighorn sheep in 1913 with enactment of the Arizona State Game code. Despite this protection, bighorn sheep numbers continued to decline during the early part of the century. In partial response, the Kofa Game Range was established in 1939 by Executive Order 8039 “for the conservation and development of natural wildlife resources, and for the protection of public grazing lands and natural forage resource.” Bighorn sheep were a driving factor in the establishment of the refuge, and much of the refuge management focuses on maintaining the sheep population. Administrative responsibility for the Kofa was shared by the U.S. Fish and Wildlife Service (FWS) and the U.S. Grazing Service until 1946. At that time the game range came under joint management of the FWS and the U.S. Bureau of Land Management (BLM). With Public Law 94-223 in 1976, the refuge came under sole control of the FWS. After passage of the Arizona Desert Wilderness Act of 1990, parts of the refuge became designated wilderness. That act and the Wilderness Act of 1964 provide general legal guidance for wilderness portions of the refuge. About 510,000 acres (798 sq mi) of the refuge’s total 665,400 acres (1040 sq mi) are designated wilderness. The Service has 5 objectives for designated wilderness management:

1. Manage so as to maintain the wilderness resource for future benefit and enjoyment;
2. Preserve the wilderness character of the biological and physical features of the area;
3. Provide opportunities for research, solitude, and primitive recreational uses;
4. Retain the same level of pre-wilderness designation condition of the area; and
5. Ensure that the work of man remain substantially unnoticeable

Kofa National Wildlife Refuge & Wilderness and New Water Mountains Wilderness Interagency Management Plan - The FWS and the BLM jointly developed the Kofa Refuge and Wilderness and New Water Mountains Wilderness Interagency Management Plan in 1996 to provide long term management guidance for the two areas. The plan was cooperatively developed and reviewed by a number of diverse public entities and government agencies, including the Arizona Game and Fish Department, and is the primary guide for managing the lands (including wilderness) within the Kofa NWR.

The Arizona Game and Fish Department (AGFD), acting under authority of the Arizona Game and Fish Commission, and Arizona Revised Statutes Title 17, has trust responsibilities for the protection and management of all wildlife in the state. The FWS, under the National Wildlife Refuge Administration Act of 1966 (as amended) and the National Wildlife Refuge Improvement Act of 1997, administers lands and waters in the National Wildlife Refuge System for the conservation, management, and restoration of fish, wildlife and plant resources and their habitats. For wildlife resources on National Wildlife Refuges within the State of Arizona, the FWS and the AGFD have always considered themselves as cooperative wildlife managers. The AGFD began pioneering and improving techniques to survey, trap and transplant bighorn sheep, and improve water availability and distribution for desert bighorn sheep in the 1950s (Russo 1956, Lee 1989, Rosenstock et al. 2004, AGFD 2005).

Public hunting was prohibited on Kofa NWR until 1956 when the refuge was opened to mule deer hunting. The first desert bighorn sheep hunt followed in 1960. Although no specific population goal has been set for the bighorn herd, the long-term population estimate since 1981 has been approximately 800, and this is considered the carrying capacity of the refuge (Figure 1). A minimum population size of 800 in the refuge has been one of the factors considered when planning sheep capture and transplant efforts (USDI 1996).

The current method of systematically surveying the entire refuge (Game Management Units 45A, B, and C – not including the New Water Mountains, which are surveyed with their respective hunt unit, 44B) by helicopter triennially was initiated in 1992. The Kofa and Castle Dome mountains are divided into blocks using geographic features in order to standardize areas flown and level of effort in each area. Sheep populations are estimated using the “Kofa Group Size Estimator” developed by Hervert et al. (1998). Sighting rates based on bighorn group (band) size range from 0.433 to 0.949:

Group size of 1 = (0.433)	Group size of 5 = (0.728)
2 = (0.507)	6 = (0.802)
3 = (0.581)	7 = (0.875)
4 = (0.654)	≥8 = (0.949)

The equation for the group expansion factor is:

$$\left(\frac{\text{Number of Groups}}{\text{Observation Rate}} (\text{Group Size}) \right) + \text{Other Groups Observed} = \text{Population Estimate}$$

Surveys from 1987-1991 were based on the same block system as is used now, but a sample of 50% of the refuge was surveyed annually and the estimate was extrapolated to the whole. This tended to result in more variable estimates than complete surveys. From 1981-1987, complete aerial surveys were conducted but the current survey blocks had not been defined. Before 1980, population estimates were based on animals observed during foot and aerial lamb surveys and water hole counts. Thus, data from before 1992 may not be comparable to data obtained after 1992. Population estimates for 1981-2006 are given in Figure 1. The 2006 survey was the first time since 1980 that the population estimate was below 600 bighorn and represents the sharpest drop recorded. Confidence intervals for these population estimates are wide.

There is evidence to suggest that this decline may not be unprecedented. Bighorn numbers were “low” in the 1960s and early 1970s (M. Haderlie, pers. comm.) before burgeoning into the 800s in the 1980s and 1990s. The estimates from the 1970-1978 Kofa Annual Narratives range between 200-375 bighorn. Population estimates from this time period are of questionable accuracy but indicate that there may have been fewer than 600 sheep for more than a decade.

Part 2. Bighorn Sheep Mortality Factors and Management Strategies

The most critical factors that influence wildlife populations are mortality and natality. Direct mortality of bighorn is most commonly caused by disease, hunting, predation, falls, drowning, or highway collisions (McKinney 2006b, Allen 1980). Indirect mortality factors include poor nutrition during drought, inter-specific competition for range/forage, habitat fragmentation, and excessive disturbance (McKinney 2006b, Allen 1980, Graham 1980, Jones 1980). The primary goal of management is to ensure wildlife populations are in balance with available habitat; that birth rates equal or exceed death rates. To ensure successful management, managers must be familiar with life history strategies of target species; must be able to detect changes in population size, distribution and structure; and must be able to quantify impacts of individual mortality factors that cumulatively affect population levels. Part 2 discusses habitat and biological factors that might cause a negative balance in the mortality-natality equation, and addresses both indirect and direct mortality factors. Management strategies for each mortality factor are presented. While some of the strategies presented may require additional processes for approval, they are all consistent with USFWS and AGFD policies. Supplements to the current management plan, the *Kofa National Wildlife Refuge & Wilderness and New Water Mountains Wilderness Interagency Management Plan and Environmental Assessment*, may be required to accomplish some of the recommended strategies necessary to recover and protect the bighorn sheep herd. A supplemental Environmental Assessment may be required for certain actions. Management strategies are also contingent on available funding.

Habitat Considerations

Two adaptations of bighorn sheep primarily define their basic habitat requirements. The first is agility on precipitous rocky slopes, which is a primary means of evading predators. The second is keen eyesight, which is a primary means of detecting predators. Consequently, desert bighorn sheep generally select open habitats that facilitate early detection of predators and allow adequate time to reach the safety of steep terrain. Large expanses lacking precipitous escape terrain will not be occupied by bighorn. Even within mountain ranges like the Kofa and Castle Dome mountains, optimal bighorn sheep habitat is patchy and the population structure is one of natural fragmentation.

Paramount to successful management of any wildlife species is habitat protection, maintenance, and/or enhancement. Cunningham (1989) reviewed several habitat evaluation models and identified two (Hansen 1980, Brown 1983) that best predicted areas used by bighorn sheep in Arizona. Most habitat models reviewed measured a variety of features to predict and quantify areas used by bighorn sheep; however, the four features common to all models included: (1) topography i.e., slope, rockiness; (2) distance from permanent water; (3) present or past bighorn use; and (4) human disturbance. The Kofa NWR contains 417 square miles of potential bighorn habitat.

Population Response to Drought

Arizona has been under drought conditions for several years. Despite an abnormally wet winter in 2005, long term drought conditions still persist across the region with multi-year precipitation deficits to overcome. Figure 2 displays the annual precipitation measured at the Kofa Mine over the past 16 years (WRCC 2007). It should be noted that even in years where annual precipitation is close to normal, it may be the result of concentrated rainfall during one month, following many hot summer months with no measurable precipitation at all. Severe drought conditions in 1996 and 2002 were likely causes for the bighorn population dips observed on the 1997 and 2003 aerial population surveys (Figure 1). McKinney et al. (2006b) observed moderate nutritional deficiencies of desert bighorn sheep adults and lambs that corresponded with drought conditions and lower production and productivity of a population in central Arizona.

If drought during the past 10 years is the primary cause of sheep decline, it must have affected adult mortality equal to lamb production or lamb survival, since lamb to adult ewe ratios did not decline. Population and age/sex ratios are estimated during each survey. Because surveys take place when the majority of lambs are close to one year old, the counts of lambs and yearlings are considered estimates of recruitment. However, actual mortality rates and productivity are unknown. Long-term lamb to ewe ratios, determined during fall aerial surveys when lambs are 6 to 12 months old, have averaged about 19 lambs per 100 ewes. During the recent decline, lamb ratios were 22 in 2003 and 25 in 2006, higher than the long-term average. Drought should also have affected bighorn habitats in game management units surrounding the Kofa equal to that on the refuge. Population estimates in those areas do not exhibit the same decline as on the Kofa (Table 1).

Determining the cause of mortality is vital to understanding which factors are contributing the most to population decline so that those factors can be addressed. Estimating survival rates and determining the cause of bighorn mortality can be accomplished by radio-collaring sheep. Although collaring 20-30% of the entire population would be ideal, (E. Rubin, pers. comm.) expending the effort and resources to collar 80-100 sheep would not be practical and might cause unnecessary stress on the population. Restricting the monitoring to just the Kofa Mountains, where declines have been most marked, would limit the target population to about 140 estimated adult females. Collaring 20-30% of these would represent 30 to 40 sheep and should allow for adequate mortality estimation. A combination of satellite GPS and VHF radio collars would be the most efficient way to obtain a wide range of data.

Objective: Estimate population parameters of Kofa bighorn sheep population.

Strategy: Continue aerial surveys to monitor population status. Additional surveys should be conducted as needed when the population is below 600.

Strategy: Seek funding for monitoring of bighorn sheep with satellite GPS and VHF radio-collars to determine cause and extent of mortality. Additional personnel would be required for monitoring in order to identify mortalities rapidly and assess the cause. Frequent (≥ 1 /week) aerial relocation flights will be required for adequate monitoring.

Water Availability

Water developments are an important wildlife management tool in the southwest (Rosenstock et al. 2004). The vast majority of research indicates that water distribution is a critical habitat variable for desert bighorn, especially during summer months when temperatures can reach 120°F (Cunningham 1989, Hanson 1980, Wilson 1975). Desert bighorn can sometimes survive on preformed water found in their food and metabolic water formed by oxidative metabolism. During summer bighorn may go without water for five to 15 days, resulting in a loss of more than 20% of the hydrated body weight (Turner 1979). During this time however, increased day length, extreme ambient temperatures, reduced moisture content of forage, and mating activities necessitate additional water intake, and thus a dependence on reliable water sources (Turner 1979, Turner and Weaver 1980).

The Kofa NWR has a large number of water sources but their utility for sheep and their reliability varies greatly. Table 2 is a list of waters considered to be critical to bighorn sheep, based on their locations in sheep habitat and documentation of sheep use from water hole counts, aerial surveys, and remote cameras. Few of the bighorn waters could be considered permanent, which means that they may go dry during the height of summer when water is needed most, or during drought years. A special water survey was conducted on June 1 of the severe drought year of 1996 and very few of the known waterholes were not dry. In addition to bighorn that may have succumbed to dehydration or malnutrition, about 20 bighorns were found to have died after becoming entrapped in tinajas with greatly lowered water levels. No similar water survey was conducted during the extreme drought year of 2002. If a water source dries up, bighorn may not move to new areas to find water (Cain 2006). It is not always known if some remote waters go dry because many are not checked regularly. Bighorn populations in surrounding hunt units, where AGFD has maintained waters, have remained fairly stable in comparison to the Kofa population, where only a few easily accessible waters are maintained (Table 1, AGFD unpubl. data). Kofa NWR waters predate wilderness designation on the refuge, and for many of these waters their maintenance by vehicle or helicopter is covered under existing management plans, or MRAs. During years of severe drought, the refuge has hauled water to Black, Charlie Died, Figueroa, Horse, Little White, and Modesti Tanks, and De La Osa Well. These waters are accessible by vehicle. In 2006, water was hauled to Black, Modesti, and Little White Tanks. New methods for reducing evaporation from water holes include floating surface covers that reduce the amount of surface area exposed while still allowing animals to drink. This method may be used at existing waters without shade covers and could reduce the need for water hauling. Some existing waters may be modified so that water levels can be easily monitored from the air. Table 2 describes what management actions should be taken to ensure designated critical waters remain full and available to sheep throughout the summer.

In addition to a need for better monitoring and maintenance of existing waterholes, a better distribution of permanent water supplies is needed to provide water in all areas of suitable sheep habitat. Some areas of habitat that could support sheep do not currently have water sources, or existing water sources are non-functional, potentially rendering that patch of habitat unavailable for sheep (Figure 3). Some existing ephemeral waters can be improved or redeveloped to hold water longer, but in some areas new waters might need to be built. The 1996 Refuge and Wilderness Plan (USDI 1996) does not specifically reference the construction of new waters in wilderness, but does mandate the FWS to “manage wilderness portions of the planning area using the minimum tools needed for maintaining an optimal desert bighorn sheep population . . .” New water developments can likely be constructed outside of wilderness, although construction in wilderness should remain an option if a wilderness location best meets wildlife management needs. Installation and monitoring of temporary waters can be used to determine if a selected water site will be used by bighorn sheep before a permanent structure is built. Redevelopment of older waters might reduce impacts to wilderness by reducing or eliminating the need for water hauling and reducing visual impacts because new developments are less obtrusive than old ones (Figure 4), which often contain concrete dams or shades that could be removed after redevelopment. Most bighorn habitat models use proximity to a permanent water source as a criterion to rank habitat quality; however opinions vary as to the maximum distance between water sources. Turner et al. (2004) found that 97% of desert bighorn collar locations were within 1.86 miles of water. Some consider the highest ranking habitat to be within two miles of a

permanent water source (Cunningham 1989, Hanson 1980); yet Wilson (1975) found desert bighorn up to three miles from water. Plans for major water renovations or new water developments will require an environmental assessment and minimum requirement analysis/minimum tool analysis. Construction of new waters and redevelopment of existing waters can be done using new techniques that place most of the structures underground, greatly reducing the visual impact of the site (Figure 4).

Objective: Ensure year-round water availability for all bighorn sheep on the Kofa NWR.

Strategy: Identify priority waters that will have water maintained at all times. This will likely require hauling water into remote locations during dry times, sometimes with the use of a helicopter. Evaporation-reducing floating covers may also be installed.

Strategy: Identify existing waters that need to be redeveloped to improve water holding capacity and efficiency. Solicit funding and volunteer labor to accomplish the projects.

Strategy: Formalize maintenance and monitoring procedures at all water sources via development and implementation of a refuge water protocol.

Strategy: Identify locations for additional water sources and begin the planning process to construct them. Use and monitor temporary water containers to test effectiveness and actual sheep use of a new water before it is constructed.

Strategy: Enlist volunteers to assist the refuge with water development monitoring and maintenance.

Biological Considerations

Bighorn sheep are generally described as a *K*-selected species, and have traits such as slow growth rates, late maturation, long gestation, low fecundity and long lives (Remington 1989). The biology of this species revolves around retention of juveniles on the home ranges of adults, versus dispersal of young from such home ranges. Bighorns have low intrinsic rates of population growth (*r*), which means their ability to recover rapidly from herd depletion is compromised relative to other species (Geist 1975). 'Disperser species' like deer (*Odocoileus spp.*) for example, are adapted to exploit early successional habitats and are considered *r*-selected: they reproduce at an early age, produce more offspring with relatively lower survival rates, but generally have the ability to recover rapidly after depletion (Krebs 1972). *K*-selected species thus appear more vulnerable to population declines and biological extinction than *r*-selected species.

Bighorns have evolved population maintenance strategies that revolve around social mechanisms that transmit home ranges and migratory patterns from one generation to the next (Geist 1975). Rather than expulsion of juveniles from the population, bighorn dispersal usually occurs

irregularly through segmentation of herds when population densities are high. These behaviors are likely adaptations to the naturally fragmented habitats bighorn sheep occupy, but barriers such as development and roads have necessitated the capture and translocation of bighorn sheep to historic ranges in facilitate re-occupancy of historical habitat. By virtue of bighorn sheep ecology and compensatory mechanisms for population maintenance, recovery from population level declines is an inherently slow process.

Factors that influence the Kofa refuge bighorn population and management strategies to mitigate these factors comprise the remainder of Part 2.

Predation

Bighorn sheep have evolved a variety of behavioral adaptations to avoid predation. A stocky build and relatively short legs provide agility on steep and rugged terrain, but preclude the fleetness necessary to escape predators in more gentle slopes. Another important adaptation is group living (Hamilton 1971, Alexander 1974). Groups provide more eyes and ears and enable members to spend more time feeding and less time surveying for predators. Studies of this phenomenon have found that a group size of six or more bighorn sheep confer an advantage in the proportion of time allocated to feeding (Berger 1978, Risenhoover and Bailey 1985). The selfish herd concept of Hamilton (1971) suggests that greater group sizes may confer further behavioral comfort. Bighorn sheep are primarily diurnal (Krausman *et al.* 1985). Coupled with keen eyesight to detect predators, diurnal behavior minimizes predation risks. Nights generally are spent on rocky slopes.

Bighorn sheep are vulnerable to a variety of predators, including mountain lions (*Puma concolor*), bobcats (*Lynx rufus*), coyotes (*Canis latrans*), and golden eagles (*Aquila chrysaetos*). All of these predators are capable of killing both adult and young bighorn sheep (Valdez and Krausman 1999). Bobcats and coyotes are the most effective predators of lambs while mountain lions are more inclined to kill adult sheep (Wehausen 1996), though Cashman *et al.* (1992) found a high incidence of bighorn lambs in lion scats in the nearby Harquahala and Harcuvar mountains. Predation by mountain lions can be a substantial source of mortality in some bighorn sheep populations (McKinney *et al.* 2006b, Kamler *et al.* 2002, Logan and Sweanor 2001, Hayes *et al.* 2000, Schafer *et al.* 2000), and mountain lions appear to be the only predators that can cause significant mortality in bighorn sheep populations that occupy suitable habitat (Sawyer and Lindzey 2002). However, Hayes *et al.* (2000) showed that cougar predation on a herd of 330 individuals lowered adult survival rates but did not cause a population decline. Logan and Sweanor (2001) estimated that 30% of bighorn mortality caused by lions was compensatory, and Ross *et al.* (1997) found that more than 1/3 of lion-killed bighorn sheep had apparent disabilities.

While predation is generally believed to rarely threaten population survival, several recent accounts across the southwest have documented cases to the contrary. Research indicates individual lions may be responsible for the majority of predation in a given area, and adverse effects are most likely to occur in small isolated desert populations (Sawyer and Lindzey 2002). For example, there is considerable evidence that increased mountain lion predation during the 1980s sent Sierra Nevada bighorn herds toward extinction in California, and given the social nature of bighorn sheep biology the herd has not recovered (Wehausen 1996). In the Mazatzal

Mountains of central Arizona, McKinney et al. (2006b) found that nutritional status and mountain lion predation during a drought influenced desert bighorn sheep population parameters and that short-term removal of mountain lions contributed to higher growth and productivity of the small, isolated population - even during periods of drought. Mountain lion predation has been the primary cause of mortalities of reintroduced bighorn sheep in the Harcuvar, Harquahala, and Bighorn mountains to the northeast of the Kofa (AGFD, unpubl. data). Mountain lion predation may have limited the success of these reintroduction efforts. The recent findings of McKinney et al. (2006a) support the idea that predation of desert bighorn sheep by mountain lions is independent of predator abundance, and thus may be more a function of learned behavior by individual predators. There are few data on the effects of mountain lion predation on large, resident herds of desert bighorn sheep.

Mountain lions have historically been suspected to be largely transient on the Kofa NWR. There are no verified records of mountain lions on the refuge between 1944 and 2001. During a research project conducted in the Kofa Mountains from 1993 through 1996, 50 bighorn sheep were radio-collared and 17 mortalities were investigated. These mortalities showed no signs of predation, and were attributed to either drowning or unknown causes, likely disease or malnutrition. From 1995-1997, Germaine et al. (2000) conducted surveys for mountain lions in 18 mountain ranges and along the Colorado and Gila rivers in southwestern Arizona, including the Kofa NWR. They confirmed the presence of only 3 individual lions (in the Mohawk and Growler Mountains) believed to be males, and suggested that a distinct, self-sustaining puma population did not currently exist in southwestern Arizona. They found no evidence of lions on the Kofa NWR.

After a female lion and 2 kittens were spotted on an aerial survey in 2003, Kofa NWR staff placed 8 active infrared and 2 passive heat- and motion-sensing digital remote cameras at water holes beginning in 2003. The refuge documented at least 5 lions on the refuge in 2006. The actual population density is unknown, but photographs of spotted juveniles or females with kittens have been obtained in successive years, suggesting a local breeding population. Bobcats and coyotes have also been observed on the remote cameras.

Little is known about the movement or specific diet of mountain lions on Kofa NWR. Three cache sites have been found on the refuge between 2001 and 2007, containing mule deer (1), bighorn sheep (1), and badger (1). In addition, two probable lion kills were identified on the refuge in 2005 and 2006: 1 mule deer and 1 bighorn sheep. However, mountain lions are also scavengers, and some carcasses or cache sites may be the result of lions scavenging upon animals they did not kill (Bauer et al. 2005). The difficulty of identifying old carcasses as definitive lion kills and the need for information about lion movements prompted expansion of the monitoring effort to include collaring lions.

Kofa NWR initiated attempts to place a satellite GPS collar on a mountain lion in January 2006. AGFD provided additional funding for the capture effort in December 2006. A young male mountain lion was captured and collared in February 2007. Through the GPS locations obtained from the collar, a kill site of a yearling ram was discovered and investigated on April 20, 2007 by refuge staff just days after the kill took place. Locations from the GPS collar will continue to be investigated for additional kill sites until the collar drops off in December 2007, or the lion is found to be an offending lion (see below).

The lion research effort should continue and be expanded to collar at least the 5 observed individuals. GPS location clusters will continue to be used to identify additional kill sites (Boyce 2005), and kills can then be definitively linked to individual lions to determine their diets and hunting patterns (Ernest et al. 2002). Diet can be further determined by collecting and analyzing scat samples from cache sites as in Ernest et al. (2002). GPS collars will also allow the mapping of lion habitat use and home range calculations. Information from lion scat collection and analysis can be used in several ways: gross examination for hair and bones provides information on prey selection, while DNA analysis of prey item bone fragments provides more detail than can be gathered in gross examination. DNA analysis of lion epithelial cells from scat can provide a population estimate, information on metapopulation linkages, and identification of specific lions preying on sheep. The refuge has collected 17 scats opportunistically since 2005 that are awaiting analysis, although a larger sample size (~37) is required for DNA analysis.

The overall impact of mountain lion predation on the sheep population is unknown. It is unlikely that lion predation alone accounts for the decline observed, but it may be additive to other sources of mortality or sufficient to prevent sheep population recovery. Predation by bobcats or coyotes may also be a contributing factor, although radio telemetry studies of coyotes on Kofa NWR and Yuma Proving Grounds showed little use of bighorn habitat (AGFD, unpubl. data).

Limited removal of individual lions identified as regularly preying on sheep may help the bighorn population recover to historical levels. Removal of lions is most effective when problem individuals can be identified and removed (Sawyer and Lindzey 2002). There is evidence that some mountain lions in bighorn sheep habitat may kill multiple sheep within a year, some may kill only one sheep within a year, and some may kill no sheep at all (Ernest et al. 2002). The key factor is that lion-sheep interactions must be studied, and offending lions, if they do exist, be identified and removed.

Ballard et al. (2001) found several factors common in case studies that dictated when removal was effective and prey populations increased. These factors included:

- Control is implemented when the prey populations are below habitat carrying capacity
- Predation is identified as a limiting factor
- Control efforts reduce predator populations enough to yield results (e.g. expected to be approximately 70% of a local predator population.)
- Control efforts are timed to be most effective (just prior to predators or prey reproduction)
- Control takes place at a focused scale (generally <400 mi²).

Reducing mortality from predation by individually-identified offending lions should follow a logical progression of 1) documenting that predation is causing significant mortality in the prey population, 2) identification and removal of the offending lion through a targeted program, and 3) continued monitoring to assess whether controlled removal is producing the desired management results.

Determining the cause of bighorn sheep mortality is another vital part of assessing the effect of predation on the Kofa population. Collaring sheep as described in the previous section on population parameters would provide important mortality data for this effort. If a bighorn

mortality is quickly identified as a lion kill or scavenge site, it provides the best starting point for snaring or tracking a lion. Bighorn mortalities attributed to other causes provide essential information about other factors that may be contributing to the population decline.

Collaring lions and sheep will also provide the necessary data for management. Tracking individual lions and their kills will allow for the targeted removal of lions that are regularly preying on bighorn sheep as opposed to a less-discriminate, landscape-level removal of lions. Offending lions (one that kills >1 bighorn within a 6 month period) could be lethally removed by a professional specialist under contract with the State. Removal of lions would be selective and only target individual lions documented to be preying regularly on bighorn sheep. If lion removals occur, they must be accompanied by careful monitoring (surveys and/or sheep survival estimates) to determine if control achieves the desired protection of bighorn sheep. GPS collars generally last 1-2 years, which would require frequent recollaring for long term monitoring efforts.

The bighorn population will be considered "recovered" when the population approaches the long-term average of 800 sheep, which based on survey data since 1981 is considered the carrying capacity of the refuge. However, the population has fluctuated between 600-800 sheep during times when no lions were documented on the refuge. As the population recovers to a level between 600-800, offending lions would no longer be removed unless there is definitive evidence an offending lion or lions are causing significant mortality. At a population estimate of 800, within a reasonable variation decided by agency personnel, all control efforts would be discontinued.

Objective: Determine cause and extent of predation when bighorn population declines are documented.

Strategy: Continue efforts to locate bighorn carcasses and predator scats. Use public reporting, ground searches, and dogs to assist this effort. Seek funding for continued assistance from professional trackers and houndsmen.

Strategy: Seek funding for monitoring of bighorn sheep with GPS or radio-collars to determine cause and extent of mortality. Collaring a minimum of 40 sheep will allow for calculation of survival rates and determination of proximate causes of mortality. Additional personnel would be required for monitoring in order to identify mortalities rapidly and assess the cause. Frequent (≥ 1 /week) aerial relocation flights will be required for adequate monitoring.

Strategy: Seek funding for monitoring of mountain lions with Argos-GPS collars to monitor habitat use and predation of bighorn sheep. One collar has already been obtained and deployed. Up to 4 more to collar all known lions would be optimal. Additional personnel may be required to assist with data management and kill verification.

Objective: Reduce predation mortality on sheep while the population is below the long-term average of 800 and there is evidence that predation is limiting bighorn population recovery.

Strategy: Implement predator control actions on offending lions. Removal of lions should be selective and only target individual lions known to be, or suspected of, preying regularly on bighorn sheep (>1 bighorn killed within a 6 month period).

Objective: Monitor recovery of the sheep population when predator control is implemented.

Strategy: Seek funding and implement annual helicopter surveys to track changes in the population to determine when recovery goals are achieved. Implement in conjunction with sheep radio-collaring as described above.

Strategy: Discontinue predator control when population estimates reach the long-term average of 800, within reasonable variation.

Disease

Disease in bighorn sheep is most prevalent when animals are stressed and during severe drought. Multiple diseases may also combine to increase mortality. Bighorns seem particularly susceptible to respiratory problems like bacterial pneumonia. *Pasturella*, for example, can be carried by healthy domestic sheep and goats, but is deadly when transmitted to wild sheep. Scabies is another common disease easily transmitted to bighorns; it was responsible for a significant decline on San Andres NWR in 1978 (Lange et al 1980). Disease transmission from burros or horses to bighorn sheep has not been substantiated; however, isolated cases of transmission from cattle to bighorn sheep have been documented (Jessup 1985, McCarty and Bailey 1994). Since the late 1800s, diseases transmitted by domestic sheep and goats have caused large, recurrent population-level declines in bighorn sheep throughout the western US. These declines have been well documented (Foreyth and Jessup 1982, Jessup 1985, McCarty and Bailey 1994), and subsequent regulations restricting contact between domesticated and wild sheep have been enacted (USDI 1998). It is imperative to keep any domestic sheep or goats well away from bighorn sheep range.

Chronic sinusitis is prevalent in bighorn sheep throughout Arizona (Bunch and Webb 1979). In severe cases, necrosis of the frontal bone and thinning of the braincase creates holes and abscessing in the brain, which is fatal. The leading theory for cause of this condition is bacterial infection secondary to necrotic bot fly larvae (*Oestrus ovis*), which are deposited in the nostrils of bighorn sheep. Evidence of chronic sinusitis has been common in the Kofa bighorn sheep herd, though it appears to be less prevalent now than during the 1980s and 1990s.

No population-level outbreaks of disease have been documented in the Kofa herd, although disease is occasionally documented. Some of the 17 radio-collared sheep mortalities discussed above showed signs of chronic sinusitis, although sinusitis could not definitively be called the cause of mortality. A lamb captured during the 2005 transplant had contagious ecthyma. A ram with chronic sinusitis was discovered in October 2006, and a hunter reported a ram coughing in

December 2006. In fall 2006, 6 bighorn sheep transplanted from the Kofa in 2005 and 2002 died of pneumonia on San Andres NWR, though this was attributed to unusual weather conditions at San Andres as opposed to any predisposition of the Kofa sheep. Blood samples have been drawn from all captured sheep over the years and tested for evidence of exposure to bovine respiratory syncytial virus (BRSV) bluetongue virus (BTV), parainfluenza III virus (PI3), contagious ecthyma virus (CE), *Chlamydia* spp. (CHLAM), and malignant catarrhal fever (MCF). In 2002 and 2005 captures, several animals were serologically positive for BRSV, CHLAM, or MCF but no clinical symptoms were noted. In these cases positive results most likely reflect past exposure or asymptomatic infection. Serum and feces are freezer banked for all animals should future analysis be required.

Objective: Monitor disease occurrence within the Kofa NWR bighorn sheep population.

Strategy: Continue to obtain blood samples from all captured sheep for disease testing. Blood sample data is based on titers, which documents exposure to a disease but not actual infection or clinical expression. However, examining several years' worth of data might reveal patterns of exposure previously unrecognized.

Strategy: Conduct additional survey effort during or following suspected disease outbreaks to monitor population status.

Objective: Reduce the potential for disease transmission between feral goats and sheep and wild bighorn sheep.

Strategy: Immediately remove any sheep, goats, or other livestock that stray onto the Kofa NWR.

Human Disturbance

Bighorn sheep tend to use the highest, most rugged areas within their home ranges for lambing. Eustis (1962), summarizing 5 years of observations on the Kofa, found that 84% of the ewes and 93% of the lambs were seen in the upper third of the Kofa Mountains during lambing seasons. Signal Peak and Castle Dome Peak are two of the most distinctive features of the refuge and as such are popular destinations for hikers. Both peaks have maps and route information posted on the internet by hikers or hiking groups. Most use of these areas occurs in the cool winter months (November-March), which strongly overlaps the peak lambing season of January-March. Actual use is unknown, although registers kept on both peaks provide a general idea.

Castle Dome:

2001: 124

2005: 197

2006: 123 (1/06-3/27/06)

Signal Peak:

2001: 42 (1/8-4/27/01)

2002: 34 (1/22-12/26/02)

2003: 25 (1/28-3/23/03)

2004: 27

2005: 48

2006: 88

These numbers are likely lower than actual use as not everyone may sign the register. In addition, some hiking groups are large. A study conducted from 1977 to 1984 documented strong reactions (immediate running, left area and did not return) from Kofa sheep in response to 1 or 2 people (Smith et al. 1986); the registers document group sizes of 18 on Castle Dome (January 2001) and 11 on Signal Peak (February 2002). Frequent human disturbance of ewes may cause them to abandon these areas for less optimal habitat, which could in turn affect lamb survival. General lambing areas have been mapped for the refuge, but additional surveys to define areas of lambing concentration would allow agency personnel to determine which areas are critical for lambing and may be subject to closure. These surveys can be done in a fixed wing aircraft at higher elevations than population surveys, which would avoid disturbing the ewes during the lambing period.

Researchers at the University of Arizona and USGS have expressed interest in conducting studies documenting the effects of public use on bighorn sheep. Obtaining funding for these studies would provide the most comprehensive data on the impacts of visitation on bighorn sheep.

Objective: Reduce the negative impacts of human recreational activities on bighorn sheep.

Strategy: Monitor visitation in important lambing areas such as Signal Peak and Castle Dome Peak. A combination of automatic cameras, volunteer observers, and research studies could provide these data. Kofa NWR is installing a satellite video system that could be used to monitor public use on Signal Peak. However, this would require personnel to analyze the video.

Strategy: Implement high-level, fixed-wing surveys of sheep habitat during lambing season to identify critical lambing areas.

Strategy: If recreational use in sensitive areas is found to be substantial, institute seasonal closures to protect the bighorn sheep. Authority for such seasonal closures can be found in the Refuge and Wilderness Management Plan of 1996. Closures should at least include the peak lambing months of January through March.

Translocations

Since the 1950s, translocation of bighorn sheep has been the primary means to reestablish populations in historical and unoccupied habitat, and to supplement dwindling populations. Singer et al. (2001) reviewed 100 translocations within six western states between 1923 and 1997 and found that 41% were successful. Successful translocations were defined as a population of >100 individuals, because one hundred animals is considered the minimum number required to assure a high probability of survival for the next 100 years (Berger 1990). Some transplants have failed entirely due to heavy predation or unknown causes (Rowland and Schmidt 1981). Many transplants in the western U.S. have consisted of groups of 12 to 40 animals; yet the minimum number suggested for direct release is 20 (Rowland and Schmidt 1981, Wilson and Douglas 1982).

From 1955 to 2000, over 1,200 bighorn sheep were transplanted within Arizona (Lee et al. 2000), and bighorn populations increased from 2,500 to over 6,000 during that time. Notable reintroductions occurred at Aravaipa and Paria canyons and Goat Mountain, all of which support viable populations of bighorn sheep today.

The first successful translocation of sheep from Kofa was in 1957 when 4 bighorn were released at the Black Gap Wildlife Management Area in west Texas. Through 2006, a total of 569 sheep have been translocated from the refuge (Table 3). Transplants of sheep from the Kofa were conducted nearly every year from 1979 through 1998 with no apparent decline in the population. The 1996 *Kofa National Wildlife Refuge & Wilderness and New Water Mountains Wilderness Interagency Management Plan and Environmental Assessment* listed the following factors for consideration in transplanting sheep:

- 1) estimated population and trends
- 2) minimum estimated population of 120 in the New Waters
- 3) minimum estimated population of 800 on the refuge
- 4) herd demographics (minimum of 50% ewes, 14 lambs:100 ewes)

These factors are always considered but are not binding in determining whether a transplant will take place. No transplants were conducted in 1991, 1996, 1997, 1999, 2000, 2003, or 2004 because of drought conditions or population estimates below 800. In 2005, 31 sheep were transplanted from the Kofa. Even though the 2003 population estimate was 623, it was thought that the population was on an upward trend and would recover quickly after the abundant 2005 rainfall and resulting improvement in habitat conditions. While not the ultimate cause of the population decline, the 2005 transplant may have contributed to the low numbers seen in the Castle Dome Mountains on the 2006 survey.

There continues to be a high demand for sheep of the *mexicana* subspecies to repopulate extirpated or dwindling populations in southern and central Arizona and New Mexico. The Kofa NWR population is the most likely source for these transplants. Sheep numbers on the Kofa are at historically low levels; therefore no transplants are currently being considered. Transplant

efforts will continue when population numbers approach the long-term average (1981-2000) of 800.

Objective: Continue management of the Kofa NWR bighorn population as a transplant source herd.

Strategy: Conduct captures and translocations according to guidelines established in the *Kofa National Wildlife Refuge & Wilderness and New Water Mountains Wilderness Interagency Management Plan and Environmental Assessment*. Special consideration must be given for transplants occurring in years without surveys.

Hunting

Hunting for desert bighorn sheep in Arizona is a once-in-a-lifetime opportunity and the demand for bighorn sheep hunting exceeds the allowable harvest. In 2005, the odds of drawing a permit were 137:1 statewide. Protection for bighorn sheep began in 1893 when the state was still a territory. Arizona's first bighorn sheep hunt was in 1953 (AGFD 2006). Every year three of the statewide tags are distributed to conservation groups such as the Arizona Desert Bighorn Sheep Society (ADBSS) and the Foundation for North American Wild Sheep (FNAWS) for auction and raffle to raise money for bighorn sheep conservation. Since 1984, over five million dollars have been raised through these sales and used specifically for bighorn sheep management and conservation in Arizona.

Hunting has been used as a population management tool for many species. Research in Alberta has shown that a healthy vigorous herd can be maintained by conservative harvest of mature rams and population maintenance below carrying capacity (Canadian Fish and Wildlife Service, 1993). Bighorn sheep hunters typically select the largest, hence the oldest, rams in the herd. In 2005, the average age of sheep taken in Arizona was 7 years old, with an average Boone & Crockett green score of 152 3/8. In Arizona, bighorn sheep are harvested under a general, male-only open season. Hunters can take only one bighorn sheep of each subspecies in their lifetime and hunters must personally check out within 3 days following the close of the season in accordance with AGFD rule 12-4-308.

AGFD has issued anywhere from 5 to 17 bighorn sheep permits for the Kofa (Units 45A, B, and C) since 1960. Hunter success rates have averaged 89% for bighorn sheep on the Kofa over the last 20 years.

Objective: Continue to offer bighorn sheep hunting opportunities consistent with sheep conservation.

Strategy: Implement annual hunt recommendations in a conservative fashion that will leave at least 80% of the Class III and IV rams post-harvest until the refuge population recovers to the long-term average of approximately 800 sheep.

Other Considerations

Livestock and Burros

No livestock grazing is allowed on the Kofa NWR, though occasional stray animals enter from BLM grazing allotments to the north and east of the refuge. BLM policy is to remove stray animals as soon as they are reported. Likewise, the refuge is not part of any burro herd management area, but some horses and burros enter the refuge from the Yuma Proving Ground in the southwest and southeast corners. A single burro has been seen in recent years in the Four Peaks-White Dike area. All livestock, burros and horses should be kept off the refuge.

Noxious and Invasive Plants

Invasive plants generally proliferate rapidly, compete with native vegetation for space, moisture, and nutrients, alter fire regimes, interrupt cycling of nutrients, and influence native plant regeneration patterns (ADOT 2002). Most of these species are highly competitive, are sometimes harmful or destructive, and are difficult to control. Invasive plants generally lack competitors or natural control mechanisms such as pathogens or predators, and thrive at the expense of native plant and animal communities. Infestations could potentially impact bighorn sheep habitat. In 2004, above average winter and spring precipitation favored large infestations of many undesirable species such as Sahara mustard (*Brassica tournefortii*), red brome (*Bromus rubens*), and common Mediterranean grass (*Schismus barbatus*). The recent spread of Sahara mustard has been restricted mainly to the fine soils in the valleys and does not appear to threaten bighorn habitat at the present time. Mediterranean grass and red brome are widespread on the refuge and have been documented in sheep habitat but are not thought to be a threat at this time.

Wildfires

Fire is uncommon on the refuge and rare in bighorn habitat. The winter rains of 2004-2005 created a heavy fuel load of annual plants. In 2005, a 26,000-acre wildfire that started on the adjoining Yuma Proving Ground burned large areas of the King Valley but did not reach into mountain habitat of bighorn sheep. In 2006, a wildfire burned 600 acres of the Ranegras Plain in the northeast corner of the refuge, but also remained outside of bighorn sheep habitat. Any wildfires that do burn in precipitous mountain habitat would likely be stopped by sparse vegetation in rocky outcrops. Wildfires often benefit bighorn sheep by opening up thick vegetation in other vegetation types, but wildfires or prescribed burns are not considered beneficial to sheep in the Sonoran Desert.

Mining

The Kofa NWR has been closed to mineral entry since 1974, but there are several active claims that were established before the area was closed. Little activity has occurred at these claims in recent years, though the potential exists for renewed use on valid claims. Mining and its related activities could cause disruption to bighorn sheep and eliminate occupied habitat. Use of heavy equipment and increased human activities, and increased traffic and noise associated with mining could cause bighorn sheep to vacate areas adjacent to active mines. According to Bristow et al., (1996) mining activity could cause bighorn sheep to stop using such areas until the mine is closed and the increased traffic along main haul roads would have the most immediate and greatest impact to movement of rams. Other mining related impacts include the use of heavy metals such as mercury and cyanide in processing. These materials at mining sites can be attractants to wildlife and cause direct mortality if not properly fenced. Research conducted on Kofa bighorn sheep in 2000 and 2001 analyzed blood, liver, and bone for trace metals. The results indicated that bighorn sheep were not bioaccumulating high concentrations of most trace metals. Most bighorn sheep tissue concentrations were similar to background concentrations in surrogate species or were below threshold levels for exposure (USFWS 2004).

Social Considerations

Political Issues and Public Outreach

Various sentiments among the public may inhibit data-driven decision making on the Kofa. For example, some wilderness proponents disapprove of new water developments in wilderness, and animal rights activists may protest the continued hunting of bighorn sheep or removal of offending mountain lions. The FWS and AGFD have made recommendations in this document for limited predator management, continued hunting, and water development that may meet with public disapproval. Planned activities will include monitoring of bighorn sheep and mountain lion populations to determine if management actions are achieving the desired population and biodiversity goals. Additional data validating the degree of predation or its consequences to a critically important desert bighorn sheep herd, while essential to making biologically sound

management decisions, will likely be of little use in resolving this social conflict. Clashing social values must be addressed. An outreach plan aimed at increasing the public's awareness of the significance of the Kofa sheep population, and current management issues is warranted.

Objective: Raise public awareness of the value of bighorn sheep on the Kofa NWR and the need for active management to maintain that value.

Strategy: FWS and AGFD should jointly develop an outreach plan to raise awareness of the importance of the bighorn sheep population on the Kofa NWR.

Volunteers

There is potential to use local volunteers to help carry out some of the tasks outlined in this plan. Volunteers from the Arizona Desert Bighorn Sheep Society and the Yuma Valley Rod and Gun Club already assist on translocation projects and water maintenance and construction projects. A large number of critical water sources have been identified in this plan as needing frequent monitoring and maintenance to maintain permanent water supplies. These water sources require a substantial time commitment to access since many require long hikes in remote wilderness areas. Management of encroaching vegetation at these sites is ongoing, and could provide opportunities for the public to help. As the public becomes more involved in managing wildlife, whether by influencing local decisions or affecting lawmaking, an understanding of wildlife needs and management options is critical. Other volunteer opportunities to involve the public in managing this important bighorn sheep herd should be further explored.

Cost Considerations

The majority of the preceding recommendations are contingent on securing additional funding. Below are preliminary anticipated costs for the recommended actions:

Breakdown of costs for the Kofa NWR desert bighorn sheep herd recovery effort (first-year).

Projects (in Priority Order)	USFWS ¹	Arizona Game & Fish Department ²	Arizona Desert Bighorn Sheep Society ³	Yuma Valley Rod & Gun Club ⁴
Purchase additional 6 Satellite GPS Mountain Lion Collars	\$20,000		\$10,000	
ARGOS Satellite Service for lion collars	\$6,720 (for one year)		\$3,400 (for one year)	
Lion Capture Specialist Contractor			\$42,800	
Aerial Surveys to Determine Status of Priority Bighorn Sheep Water Sources w/ AGFD aircraft		\$5,000		
October 2007 Bighorn Sheep Census	\$19,000/\$6,000		\$25,000	
Redevelop two existing water sources -Yaqui and McPherson Tanks		\$56,000 (including contractor to transport materials to sites)		\$8,100
Supplement water in Frenchman, Maggot, Saguaro, Old Moonshine Tanks		\$8,000		
Supplement water by vehicle and fire hose in remaining priority waters	\$7,500			
Purchase 14 Satellite GPS radio collars for bighorn sheep			\$65,000	
Sheep capture (to attach collars)			\$20,000	
30 VHF Radio Collars for sheep			\$9,000	
ARGOS Satellite Service for sheep collars			\$16,800 (for one year)	
Technician for monitoring sheep		\$15,000 (for one year)		
TrailMaster Remote Cameras				\$3,000
Totals⁵	\$26,500/\$32,720	\$69,000/\$15,000	\$138,000/\$54,000	\$0/\$11,000
Subtotals	\$59,220	\$84,000	\$192,000	\$11,000
Grand Total	\$346,220			

¹ Kofa NWR will fund the proposed sheep survey from its annual recurring 1261 base allocation (2004 RONS) for survey work. It is anticipated that these costs will be incurred annually until the herd is recovered. Water supplementation by vehicle will be covered under the Refuge's 1262 base allocation.

² AGFD has also applied for sheep tag funds to purchase VHF collars and to potentially cover half the cost of the sheep survey.

³ ADBSS committed a total of \$138,000 at their Board of Directors Meeting on April 11, 2007 in Phoenix. They are likely to fund other activities as listed above and intend to provide on-the-ground support for projects (e.g., in-kind labor and food for participants).

⁴ YVRGC has already assisted by purchasing remote cameras for the mountain lion study and they may purchase additional cameras and assist with their maintenance. Their typical contribution to projects includes in-kind labor and actual cost of food for participants.

⁵ The funding amounts highlighted in "bold" are commitments to date by each organization. The remaining funding amounts are proposed, but to date uncommitted.

Part 3. Implementation

The primary purpose of Part 3 is to assist managers in the FWS and AGFD with monitoring implementation of this management plan. To facilitate this monitoring, all proposed strategies have been listed in matrix form. Management strategies have been listed in the order they appear in Part 2.

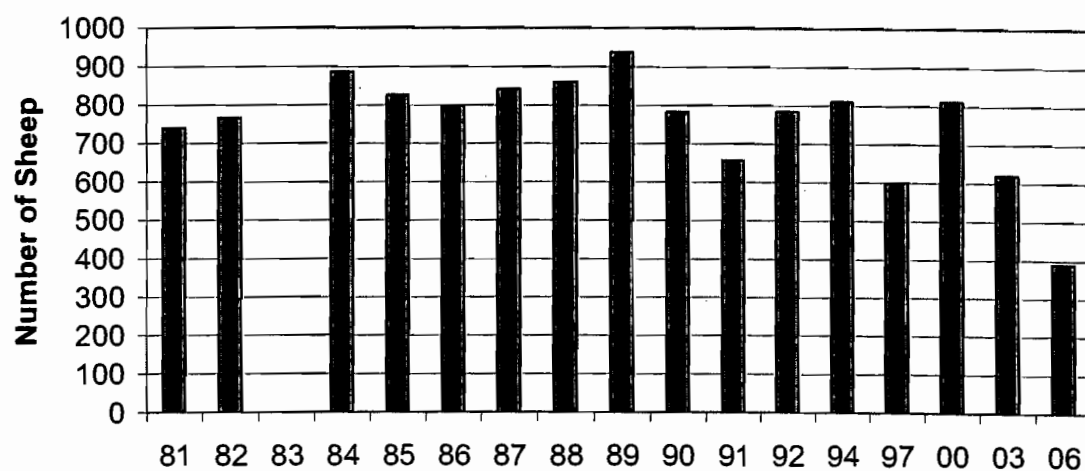
Implementation Matrix

Section	Objective	Strategy	Owner	Timeline
Habitat Considerations				
Population response to drought	Estimate population parameters	Conduct additional surveys as needed		
		Collar sheep to estimate population parameters		
Water availability	Improve water distribution for bighorn.	Identify critical sheep waters for maintenance and water hauling		
		Identify existing waters that require redevelopment		
		Identify areas suitable for new water development		
		Complete planning requirements for water (re)development and hauling		
		Formalize maintenance and monitoring procedures at each water source via implementation of a refuge water protocol		
		Work with NGOs and enlist volunteers to assist in monitoring and maintenance.		
Biological Considerations				
Predation	Quantify predation when bighorn numbers are down	Search for bighorn sheep carcasses and predator scats.		
		Monitor bighorn sheep with radio-collars to determine extent of predation		
		Monitor lions with GPS collars to document sheep kills.		
		Implement predator control on offending lions.		
	Monitor effectiveness of predator control.	Seek funding for additional surveys.		

Section	Objective	Strategy	Owner	Timeline
Biological Considerations (continued)				
Disease Transmission	Monitor bighorn disease occurrence	Obtain blood samples from all captured sheep. Conduct additional population surveys following suspected disease outbreaks.		
	Reduce potential for disease transmission	Remove stray feral sheep, goats and other livestock		
Human disturbance		Identify important lambing areas. Conduct aerial surveys of lambing grounds.		
	Reduce negative impacts of human disturbance	Monitor visitation in lambing areas.		
		Institute seasonal closures of sensitive areas if required.		
Transplants	Maintain transplant program	Conduct transplants when populations meet management criteria		
Harvest	Offer bighorn sheep hunting opportunities consistent with sheep conservation.	Amend hunt guidelines.		
Political Issues and Public Outreach	Raise public awareness of bighorn sheep in the Kofa Mountains	Develop outreach plan		

Figures

Figure 1. Bighorn sheep population estimates for Kofa NWR (Unit 45), 1981-2006*.



* Population estimates from 1981-1986 and 1987-1991 were obtained using different survey methods than estimates from 1992-2006. Data from before 1992 are not directly comparable to data obtained after 1992 but can be used to show trends.

Figure 2. Annual precipitation at Kofa Mine station in the Kofa Mountains. Blue line represents 30-year mean.

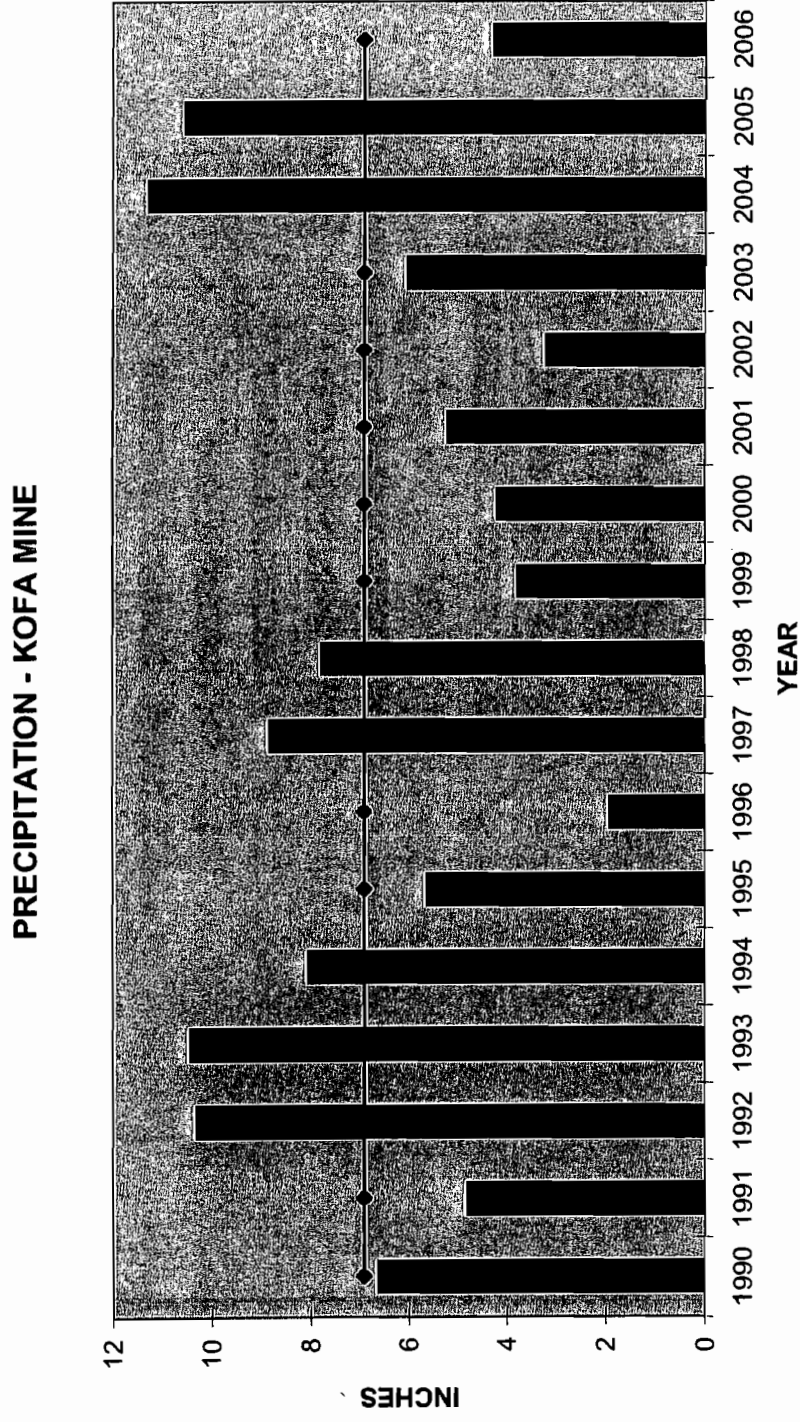


Figure 3. Bighorn sheep waters with 3-mile radius circle drawn around “permanent” waterholes (red dots). Habitat outside circles lacks adequate water supplies. Green and blue dots are bighorn locations from fall surveys 1992-2003.

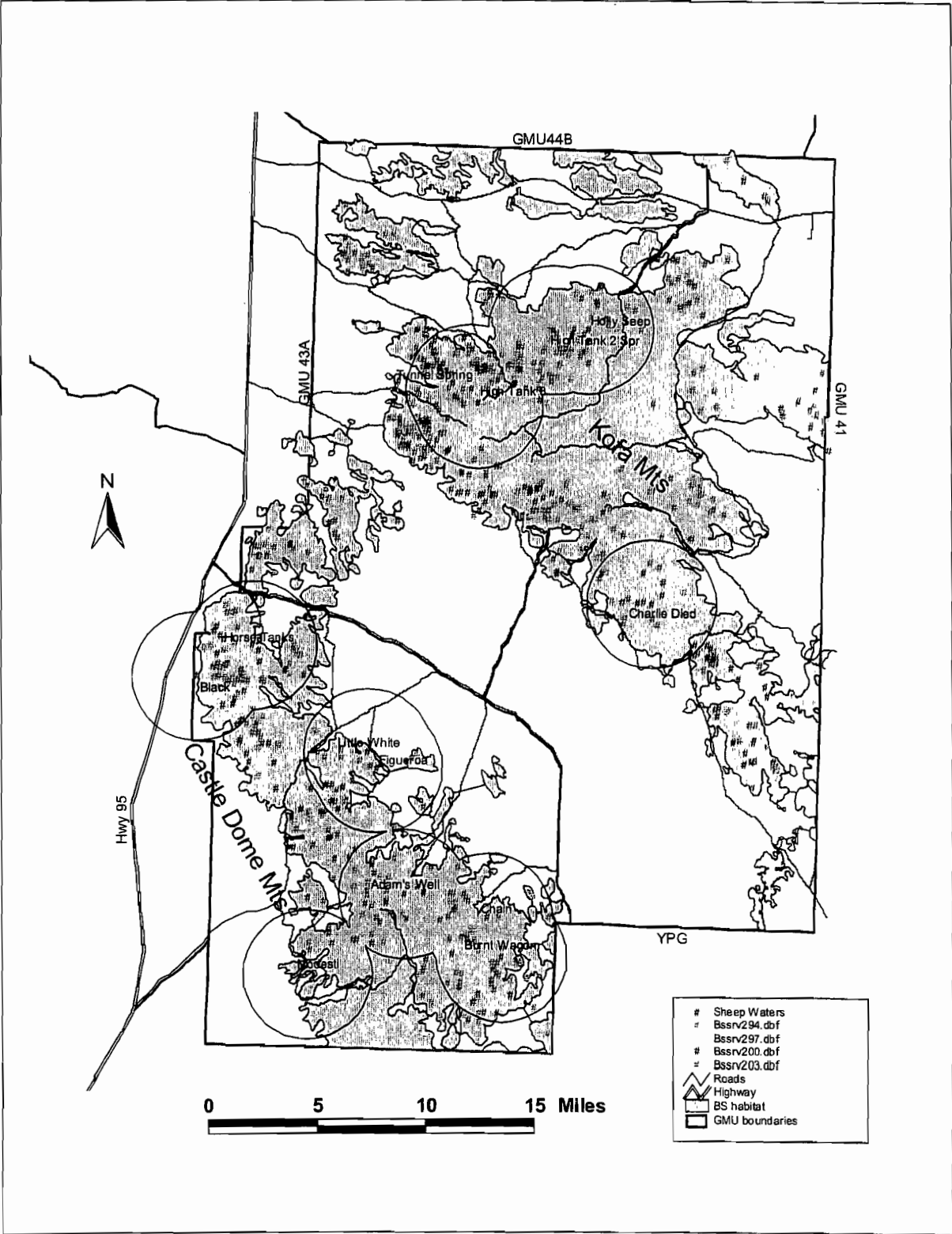


Figure 4. Example of bighorn sheep water in the Mohawk Mountains, Arizona (not on the refuge) constructed with new techniques that minimize visual impact. Most water storage and collection components are buried and not visible.



Tables

Table 1. Population estimates of bighorn sheep in game management units that surround the Kofa NWR (Units 45 and 44BS).

Unit	40BW (Gila Mts)	43B	44BS	41W	45
1998		207			
1999			116		
2000	69			107	812
2001		190			
2002			123		
2003				119	620
2004		250			
2005			71		
2006	100			101	390

Table 2. Critical bighorn sheep waters on the Kofa and recommended management actions.

Name	Type of Water	Management Unit	Suggested maintenance/management action
Cereus Tank†	Developed tinaja	45A	Vehicle water supplementation, evaporative cover
High Tank 8	Developed tinaja	45A	Supplementation not expected in 2007
High Tank 2 Spring	Developed spring	45A	Supplementation not expected in 2007
Maggot Tank†	Tinaja	45A	Helicopter water supplementation, evaporative cover
Hidden Valley Tank†	Developed tinaja	45A	Vehicle water supplementation, evaporative cover
Tunnel Springs	Developed spring	45A	Supplementation not expected in 2007
High Tank 6	Developed tinaja	45A	Vehicle water supplementation, evaporative cover
Frenchman Tank†	Developed tinaja	45B	Helicopter or vehicle supplementation TBD, evaporative cover
Yaqui Tank†	Developed tinaja	45B	Vehicle water supplementation, evaporative cover Slated for redevelopment
White Dike (High Tank 3)†	Developed tinaja	45B	Helicopter water supplementation, evaporative cover
Charlie Died*	Buried system	45B	Vehicle water supplementation
Moonshine Tank†	Developed tinaja	45B	Helicopter water supplementation Slated for redevelopment
Old Moonshine Tank†	Tinaja	45B	Helicopter water supplementation, evaporative cover
Adam's Well*	Well	45C	Supplementation not expected in 2007
Horse Tank*	Developed tinaja	45C	Vehicle water supplementation
Black Tank*	Developed tinaja	45C	Vehicle water supplementation
Little White Tanks*	Developed tinaja	45C	Vehicle water supplementation
Saguaro Tank†	Developed tinaja	45C	Helicopter water supplementation, evaporative cover
Modesti Tank	Buried system	45C	Vehicle water supplementation
Chain Tank*	Developed tinaja	45C	Supplementation not expected in 2007
Burnt Wagon Tank	Tinaja	45C	Supplementation not expected in 2007, evaporative cover
McPherson Tank	Tinaja	45C	Slated for redevelopment
Livingston Hills	New temporary water	45A	Placed and maintained by vehicle
Engesser Pass	New temporary water	45B	Placed and maintained by vehicle

*Tank in wilderness, supplementing water covered by CCP or other documentation

†Tank in wilderness, MRA needed prior to water supplementation

Table 3. History of translocations from Kofa National Wildlife Refuge.

Year	Number Captured	Number Released	Release Location
1957	14	4	Black Gap WMA, Texas
1958	3	1	Black Gap WMA, Texas
1958	1	1	Aravaipa Canyon, Arizona
1959	16	8	Black Gap WMA, Texas
		3	Aravaipa Canyon, Arizona
1966	1	1	Aravaipa Canyon, Arizona
1967	6	1	Aravaipa Canyon, Arizona
1968	4	1	Aravaipa Canyon, Arizona
1979	2	2	Black Gap WMA, Texas
1979	9	7	Devils Canyon, Grand Junction, Colorado
1980	6	6	Indian Springs Canyon and Goat Mt, Mazatzal Mts, Arizona
1980	6	6	Peloncillo Mts, New Mexico
1981	14	12	Painted Cliffs and Goat Mt, Mazatzal Mts, Arizona
1981	16	16	Redfield Canyon, Galiuro Mts, Arizona
1982	6	4	Peloncillo Mts, New Mexico
		2	Redfield Canyon, Galiuro Mts, Arizona
1982	12	11	Peloncillo Mts, New Mexico
1983	24	23	Horse Mesa and Bronco Butte, Superstition Mts, Arizona
1984	32	30	Millsite Canyon, Superstition Mts, Arizona
1985	22	21	Ives Peak, Black Mts, Arizona
1985	22	20	Lion Mt, Mazatzal Mts, Arizona
1986	31	31	Peloncillo Mts, Arizona
1987	30	30	Tortilla Mt, Superstition Mts, Arizona
1988	32	29	Galiuro Mts, Arizona
		2	University of Arizona, Arizona
1989	30	30	Tortilla Mt, Superstition Mts, Arizona
1990	16	15	Peloncillo Mts, Arizona
1992	25	24	Horse Mesa, Superstition Mts, Arizona

Table 3. Translocations from Kofa NWR (continued).

1993	31		30	Sauceda Mts, Arizona
1994	30		30	Granite Wash Mts, Arizona
1995	26		26	Harcuvar Mts, Arizona
2001	27		25	East Harcuvar Mts, Arizona
			2	Arizona-Sonora Desert Museum, Arizona
2002	21		20	San Andres NWR, New Mexico
2005	31		30	San Andres NWR, New Mexico
			1	Bighorn Mts, Arizona

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